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A mortality study among workers in an English asbestos factory

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ABSTRACT The previous report on this cohort study of workers in an asbestos textile factory (Knox *et al.*, 1968) showed little evidence of increased mortality among workers who had entered the factory after the implementation in 1932 of the first Asbestos Industry Regulations (1931) but observed that no firm conclusions could be drawn, as little carcinogenic effect would be expected for 20 years after first exposure. A further $8\frac{1}{2}$ years of follow-up has revealed some asbestos-related disease in this latter group, although very much less than for employees first exposed before 1933. Among the 963 workers first exposed in 1933 or later, mortality was increased for carcinoma of the bronchus (31 deaths; 19·3 expected for all lung cancers) and non-malignant respiratory disease (35 deaths, 25·0 expected), and a further 5 deaths were attributed to pleural mesothelioma.

This cohort study of workers in an asbestos textile factory in the North of England has been the subject of three previous reports (Doll, 1955; Knox *et al.*, 1965; Knox *et al.*, 1968). These dealt particularly with mortality from lung cancer and respiratory disease in workers exposed to the high dust levels preceding the 1931 Asbestos Industry Regulations, and examined the dependence of lung cancer incidence on age and duration of exposure. The last report (Knox *et al.*, 1968) showed little evidence of increased mortality among workers who had entered the factory after the implementation of the 1931 regulations in 1933, but pointed out that no firm conclusions could be drawn because little carcinogenic effect would be expected for 20 years after first exposure. The present report is concerned particularly with the post-1932 population which, although exposed to dust levels which were higher than the present permitted levels, was employed during a time of improving dust control and plant modernisation.

Methods

This study is based on the 1106 men and women who by the end of 1972 had worked for over 10 years in scheduled (dust risk) areas of the factory. The total population is divided into five cohorts on the basis of duration and period of work in scheduled areas (Table 1). A more detailed account of the cohorts and other aspects of the study is given in the previous report (Knox *et al.*, 1968). Re-examination of personnel records since the last report showed that a further 23 workers were eligible for inclusion in cohorts 1 and 2; in addition 205 workers who have completed 10 years employment since June 1966 have been added to cohorts 3, 4 and 5. The study thus comprises 822 men and 284 women. This population was followed up to 31 December 1974 using factory personnel records and the National Health Service Central Register.

Results

Twenty-two (2·0%) workers could not be traced and 13 (1·2%) who are recorded in the NHS Central Register have emigrated or are not currently registered with a general practitioner. The remaining 1071 (96·8%) have been followed up to the end of 1974. The numbers of deaths in each group attributed to lung cancer*, other cancers, respiratory diseases

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*Deaths due to mesothelioma of the pleura are included under lung cancer. These are coded as benign (228, eighth revision of the *International Classification of Diseases* (World Health Organization, 1967), (8th ICD)) unless the word malignant or the site appears on the death certificate.

Table 1 *Number of workers in each exposure cohort*

Cohort	*Sex*	*Years in scheduled areas*	*Years in scheduled areas before 1933*	*Number*	*Person-years observation*
1	Male	20 or more	10 or more	69	1006
2	Male	20 or more	Less than 10	74	1397
3	Male	20 or more	None	263	2048
4	Male	10-19	None	679*	7261
5	Female	10 or more	None	284	4360
Total				1106	16072

*Including the 263 men in cohort 3 before they had completed 20 years in scheduled areas.

Table 2 *Number of deaths observed and expected, by exposure cohort and cause*

Cause of death†	*Cohort*	*Observed deaths*‡	*Expected deaths*	*Ratio observed/expected*	*Probability of observed number or more*
Lung cancer and pleural mesothelioma (162, 163 and 228)	1	15 (2)	1·49	10·1	<0·001
	2	10 (3)	3·05	3·3	0·001
	3	9 (2)	5·56	1·6	0·111
	4	24 (2)	12·82	1·9	0·003
	5	3 (1)	0·92	3·3	0·066
Other cancers (140-239)	1	8	4·14	1·9	0·060
	2	3	4·29	0·7	0·801
	3	6	6·61	0·9	0·647
	4	11	17·78	0·6	0·966
	5	6	7·63	0·8	0·772
Respiratory diseases (460-519)	1	14	3·86	3·6	<0·001
	2	7	4·32	1·6	0·147
	3	8	5·93	1·3	0·246
	4	23	17·28	1·3	0·108
	5	4	1·81	2·2	0·110
Other causes	1	27	18·29	1·5	0·033
	2	23	17·89	1·3	0·139
	3	36	26·57	1·4	0·047
	4	69*	75·06	0·9	0·773
	5	11	13·34	0·8	0·776
All causes	1	64	27·78	2·3	<0·001
	2	43	29·55	1·5	0·012
	3	59	44·67	1·3	0·023
	4	127	122·94	1·0	0·369
	5	24	23·70	1·0	0·503

†Coded according to the eighth revision of the *International Classification of Diseases* (World Health Organization, 1967).
‡Deaths due to pleural mesothelioma are included in the observed number for lung cancer and also given separately in parentheses.
*Includes one case in which a pleural mesothelioma was a contributory cause of death.

and other causes are compared in Table 2 with the numbers expected. These expected numbers were calculated in the usual way from national death-rates by five-year periods and five-year age-groups. To ensure that expected numbers are not underestimated, emigrants and those lost to follow-up were assumed to be alive on 31 December 1974. Deaths before 1 January 1931 or after the age of 85 are ignored, however, and expected numbers are calculated accordingly. Lung cancer mortality in Rochdale was lower than the national average among men (standardised mortality ratio (SMR) = 87) and similar for women (SMR = 104) in 1959-63 Registrar General, 1971).

Workers first exposed before 1933 (cohorts 1 and 2) suffered a marked excess of lung cancer and respiratory disease, particularly those with 10 or more years' exposure prior to 1933. There is also some excess mortality from lung cancer and mesothelioma (36 observed, 19·3 expected; P§ < 0·001) and respiratory disease (35 observed, 25·0 expected; P = 0·03) in those who entered scheduled areas after 1 January 1933 (cohorts 3, 4 and 5 combined), although the excess is very much less than in the first two cohorts. The slight excess of circulatory disease in cohort 3 reported at the previous follow-

§All significance levels give the probability of observing the actual number of deaths or more in a Poisson distribution with the expected mean.

up (Knox *et al.*, 1968) has not increased (27 observed, 20·64 expected; 9 observed, 4·03 expected in the 1968 report), while in cohorts 4 and 5 there was a matching deficit (50 observed, 60·10 expected). The inference that this was probably a chance observation thus seems confirmed. There were 16 deaths attributable to gastrointestinal cancers (151-154, 8th ICD) compared with 15·70 expected. No excess for any of these rubrics approached statistical significance in any cohort, and no peritoneal mesothelioma was reported.

To distinguish exposure immediately after 1933 from that under present conditions, cohorts 3, 4 and 5 were divided into those first entering scheduled areas from 1933 to 1950 and those starting later. 1951 was taken as the start of the modern period because it was the year in which routine dust sampling was initiated, although it is known that dust levels in some areas remained high. Observed and expected deaths for those first exposed between 1933 and 1950 and those first exposed later are shown in Table 3. There is clear evidence of some excess of lung cancer and respiratory deaths among those first exposed between 1933 and 1950, although very much less than in cohorts 1 and 2. There have been few deaths among those first exposed in 1951 or subsequently, but there still appears to be an excess of deaths from lung cancer 15 or more years after first exposure (5 observed, 1·86 expected: (P = 0·04). This is shown in Table 4, in which deaths from lung cancer including pleural mesothelioma in these groups are distributed according to the time since first exposure; the relative risk increases progressively with time since first exposure in both groups.

The six employees first exposed after 1950 who died of lung cancer were all men and smokers; five worked in areas where dust levels were high in 1951, and one may have been exposed to asbestos dust from 1925 to 1930 in a previous occupation. No case of mesothelioma has occurred in the population first exposed after 1950, although in view of the long latent period none would yet be expected (Newhouse and Berry, 1976). An approximately multiplicative effect of asbestos exposure and cigarette smoking on lung cancer incidence has been suggested (Doll, 1971; Berry *et al.*, 1972), but without detailed smoking histories, which are being collected for the future, this cannot be quantified in this study. Asbestosis was found by the Pneumoconiosis Medical Board at post-mortem examination in three of the six cases. The numbers are too small for the magnitude of the excess of lung cancer in those first employed after 1950 to be estimated with any precision.

DUST LEVELS

The implementation of the Asbestos Industry Regulations (1931) started a drive to improve dust control interrupted only by the relaxation of

Table 3 *Number of deaths observed and expected, by date of first exposure*

Cohort	*Cause*	*Observed deaths*‡	*Expected deaths*	*Ratio observed/expected*	*Probability of observed number or more*
Men and women first exposed 1933-1950 (n = 616)	Lung cancer	30 (5)	16·10	1·9	0·001
	Other cancers	20	27·00	0·7	0·931
	Respiratory	33	21·91	1·5	0·016
	Other causes	103*	97·96	1·1	0·318
Men and women first exposed 1951 or later (n = 347)	Lung cancer	6 (0)	3·20	1·9	0·105
	Other cancers	3	5·02	0·6	0·877
	Respiratory	2	3·11	0·6	0·817
	Other causes	13	17·01	0·8	0·865

‡Deaths due to pleural mesothelioma are included in the observed number for lung cancer and also given separately in parentheses.
Includes one case in which a pleural mesothelioma was a contributory cause of death.

Table 4 *Observed and expected deaths from lung cancer by date of first exposure and time since first exposure*

Cohort	*Period since first entering scheduled area (years)*	*Observed deaths*‡	*Expected deaths*	*Ratio observed/expected*	*Probability of observed number or more*
Men and women first exposed 1933-1950 (n = 616)	10-14	3 (0)	1·85	1·6	0·283
	15-19	4 (0)	3·09	1·3	0·373
	20 and over	23 (5)	11·16	2·1	0·001
	Total	30 (5)	16·10	1·9	0·001
Men and women first exposed 1951 or later (n = 347)	10-14	1	1·34	0·7	0·738
	15-19 }	3 } 5	1·34 } 1·86	2·2 } 2·7	0·152 } 0·041
	20 and over }	2 }	0·52 }	3·8 }	0·096 }
	Total	6 (0)	3·20	1·9	0·105

‡Deaths from pleural mesothelioma are included in the observed number for lung cancer and also given separately in parentheses.

Table 5 *Dust levels accompanying different textile processes, 1952-1974*

Department	*Process*	*Yearly mean dust levels*				
		Casella thermal precipitator (particles per cc)		*Long running thermal precipitator or cellulose membrane (fibres per cc)*		
		1952	*1960*	*1961*	*1966*	*1974*
Fiberising	Mixing	500	—	—	—	—
	Opening	440	now totally enclosed			
	Bag slitting	—	110	5	4	2
	Mechanical bagging	—	120	4	5	3
Carding	Fine cards	200	200	6	6	3
	Medium cards	810	400	8	8	3
	Coarse cards	1140	420	7	8	4
	Electrical sliver cards	490	260	5	2	2
Spinning	Fine spinning	170	110	4	3	1
	Roving frames	510	150	5	6	3
	Intermediate frames	530	100	5	6	4
Weaving	Beaming	190	220	8	4	<1
	Pirn winding	350	130	3	3	<1
	Cloth weaving	180	140	3	2	<1
	Listing weaving	130	110	2	1	<1
Plaiting	Plaiting	140	80	4	4	3

Table 6 *Mean dust levels and number of men exposed to them in selected years from 1936-1972 (BOHS data)*

Year	*Mean dust level (fibres per cc)*	*Number of men*	*Percentage exposed at various levels*		
			$f \leqslant 2$	$2 < f \leqslant 5$	$f > 5$
1936	13·3	15	0	0	100
1941	14·5	49	4	0	96
1946	13·2	87	2	2	96
1951	10·8	189	2	9	89
1952	10·9	219	2	9	89
1956	5·3	294	2	40	58
1960	5·4	349	6	31	63
1961	5 2	351	6	35	59
1966	5·4	359	23	22	55
1971	3·4	258	32	43	25
1972	2·9	233	32	65	3

f = fibres per cc.

regulations during the second world war, when working hours were increased and blackout restrictions interfered with ventilation. Technical improvements since 1933 included major changes between 1953 and 1957, and dust levels have fallen by approximately 50-80% throughout the factory over the last 25 years, the largest reductions being in areas where levels were highest in 1961 (Table 5). Data on numbers of employees and dust levels in different areas of the factory submitted by the company to the British Occupational Hygiene Society (BOHS) Subcommittee on Asbestos have also been made available to us (Table 6). Routine dust measurements were not made prior to 1951, but it is estimated that levels in 1933 were at least 1·5 times the average between 1951 and 1955, and the estimates in Table 6 are based on this figure. It was assumed that levels remained constant from 1933 to 1945 and then fell steadily between 1945 and 1950. Mean dust levels were weighted by the number of men exposed at each level, so that the apparent increase between 1936 and 1941 reflects a fall in the proportion of employees working in *low* dust areas rather than a general increase in estimated dust levels. The estimates in Table 6 are based on 379 men with no exposure before 1933, still employed at some time between 1966 and 1972, who had worked for at least 10 years in scheduled areas. All dust levels have been estimated from fixed sampling points.

It is apparent from these estimates that the mean dust level has been below five fibres/cc only in the last decade. In 1951 the mean dust level was 10·8 fibres/cc, and 89% of the men in the BOHS series were exposed to mean levels greater than 5 fibres/cc in that year. By 1972 the mean was 2·9 fibres/cc, and only 3% were exposed to a mean level greater than 5 fibres/cc, 65% to a mean level between 2-5 fibres/cc and 32% to a mean level below 2 fibres/cc (Table 6).

Discussion

It is difficult to interpret the relevance of these results to modern conditions. The object of this study was to establish the value of technical improvements since 1931, but as there is a delay of 15 or more years between first exposure and any resulting cancer our results do not reflect the effects of working conditions over the last 15 or 20 years. We therefore propose to continue follow-up on those entering scheduled areas since 1951, and subsequent analysis will focus on the relationship between mortality and dust levels at first exposure. Such estimates will contribute to the establishment of hygiene standards designed to minimise asbestosis and lung cancer.

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